

RESOURCE ALLOCATION PLANNING WITH INTERNATIONAL COMPONENTS

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ABSTRACT

Dumas, Briggs, Reid and Smith (1989) describe the need for identifying mutually acceptable methodologies for developing standard agreements for the exchange of tracking time or facility use among international components. One possible starting point is the current process used at the Jet Propulsion Laboratory (JPL) in planning the use of tracking resources.

While there is a significant promise of better resource utilization by international cooperative agreements, there is a serious challenge to provide convenient user participation given the separate project and network locations. Coordination among users and facility providers will require a more decentralized communication process and a wider variety of automated planning tools to help users find potential exchanges. This paper provides a framework in which international cooperation in the utilization of ground based space communication systems can be facilitated.

Key Words: Resource Allocation Planning, Ground Data Systems, International Collaborations, Scheduling

1. INTRODUCTION

Dumas, Briggs, Reid, and Smith (1989), hereafter identified as DBRS, forcefully argued for increased efforts to facilitate, through more routine agreements, international collaboration in Deep Space communication and tracking. They pointed out that the scope of international cross-support has expanded over the years due to the increased trend toward international missions (eg. Ulysses and TOPEX) and international investigations and instruments on spacecraft (eg. Cassini and Huygens probe). The benefits, identified by

DBRS, of international coordination in which ground networks are used by other agencies and nations (this is defined as *cross-support*) include:

- The expanded use of arraying to increase receiving capabilities
- The progression toward very long baseline interferometry (VLBI), and
- The science for tracking exchanges that have allowed increased data capture for high activity periods and continuous coverage by agencies that lack world-wide coverage.

In order to facilitate the planning of international resource exchanges and cooperation, DBRS suggest that rather than the current mission-by-mission ad hoc development of cross-support agreements, exchanges of tracking time or facility use should become more standardized. In addition, active participation by all users and networks through better communication and software tools would provide a quick and convenient method to examine the range of trading options, and therefore expanding the amount of data capture from deep space missions.

The Consultative Committee for Space Data Systems (CCSDS) is an international interagency organization that provides a forum for space agencies to develop recommendations on standard techniques for data handling. The CCSDS "green book" provides a catalog of all available tracking facilities and their basic characteristics. Through this committee, significant headway has been made by the operations portion of the cross-support venture in identifying available resource capabilities. However, while much work has been done on

improving data standards and communication frequencies among ground data systems, there has not been much effort in standardizing cross-support agreements and integrating plans. The planning portion of the cross-support equation has not been well developed. Currently, there does not exist a common database in which individual agency network plans can be viewed. Thus, the ability to identify exchanges that can increase the amount of tracking for all agencies is not an easy task. Indeed, routine attempts to find beneficial trades of tracking time are not possible given the current structure of planning databases and software tools.

The purpose of this paper is to expand on the theme developed by DBRS focusing primarily on integrating and "standardizing" planning databases, so that beneficial trades can be found among participating networks. The same effort that has been undertaken to standardized data handling should be extended to the requirements and planning databases. This effort would then allow for simple standardized tracking exchanges to occur. The recommendations contained in this paper focus on the following four items:

1. A standardized requirements database for all participating "agencies" should be accessible by all planning teams and users.
2. Viewperiod data and mission set information should be made accessible to all users and planning teams.
3. Current resource plans and activities/events should be standardized and easily accessible.
4. Possible process flow of international exchanges.

If the planning databases of each agency can be "standardized", then the planning analysts for each agency will be able to more readily identify likely candidates for feasible cross-support exchanges. Once databases are standardized, then the next step would be to construct simple arrangements that can implement exchanges.

2. RESOURCE ALLOCATION PLANNING (RAP) PRIMER FOR DEEP SPACE NETWORK RESOURCES

In this section we will provide a brief overview of how resource allocation planning is conducted for NASA at JPL. The purpose of this primer is two-fold:

1. Describe the basic data structure of the JPL planning database; and
2. To provide a starting place for developing planning interfaces for international cross-support activities.

The process of matching spacecraft tracking requirements with available NASA tracking facilities has evolved from a pencil and paper activity to its present state as an semi-automated computerized system with look-ahead planning algorithms (see Berner et al (1989), Johnson and Werntz (1987)). The current system allows for plans extending over ten years (see JPL-RAP summary document). The RAP process provides allocation plans for tracking resources (antenna time) from 8 weeks to 10 years prior to execution. The plans range from generic levels of mission tracking support to detailed minute by minute track assignments. The RAP process has the ability to identify high activity-contention periods early (5-7 years in advance) and maintains a centralized database of requirements, major events, allocations and spacecraft viewperiods. The RAP process relies on four major components to forecast and plan resource use for NASA's Deep Space Network (DSN):

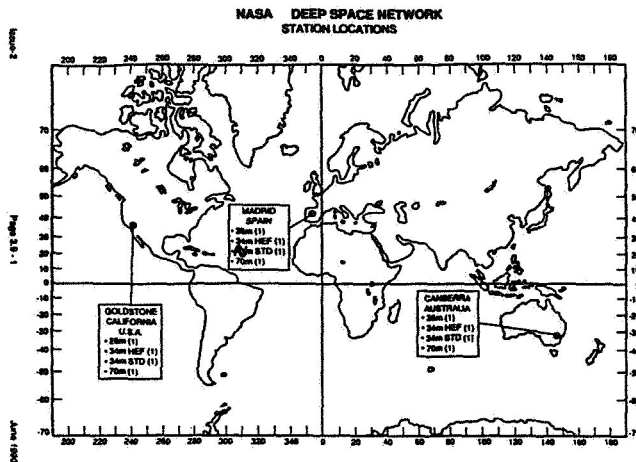
1. Network resource availability;
2. User requirements/requests and major events;
3. Planning constraints; and
4. Planning control.

2.1 Tracking Resources

JPL's Office of Telecommunications and Data Acquisition (TDA) maintains the configuration and operating policy for the DSN resources pictured in Figure 1. Information concerning the capabilities of the network, future plans, modifications and maintenance activities are provided to the Resource Analysis Team (RAT) by TDA.

Given the network plans and maintenance requirements, a profile of antenna location, availability and capabilities can be constructed. The resource profile consists of the number of available tracking hours at each station. Within the resource profile mission requirements are then planned.

Figure 1
DSN Resource Configuration Map



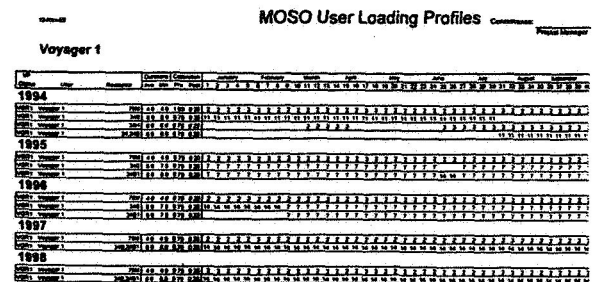
Source: CCSDS Green Book2.2

2.2 User Requirements

In addition to DSN maintenance requirements, each mission submits a 10 year plan of requirements and major events to the planning group. The set of missions used to develop a resource allocation plan is provided by a mission set that is developed by the RAT from NASA headquarters inputs. The current list of users in the JPL Resource Allocation Planning database can be found in Appendix A. The initial set of requirements submitted by users are generic in nature and list the number of "passes" per week (including pre and post track calibration requirements) and antenna requirements (eg. X-band, 70M) to support their mission. A pass is typically an 8 hour track but it can be shorter or longer depending on the tracking event. In addition, special requests such as overlap coverage from two stations can be requested along with spacing between passes can be requested. Figure 2

supplies a requirements input from a JPL mission. The input form lists, for each year, subnetwork, (we define a *subnetwork* as the system of either the 34 meter standard antennae (34S); 34 meter high efficiency antennae (34H); the 34 meter beam wave guide antennae (34B); or the 70 meter (70M) antennae) and week (1-52), the number of passes requested. For example, in Figure 2, in 1998 this mission is requesting 14 passes a week on either the 34S or 34B subnetworks.

Figure 2
User Requirement Form



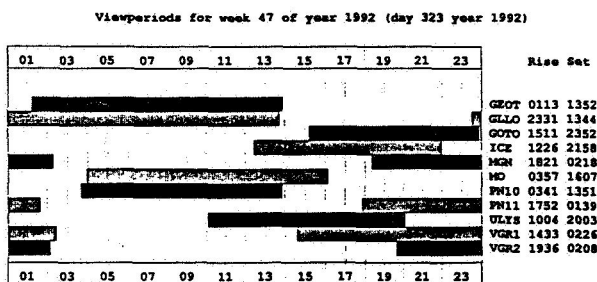
Source: JPL-RAP Database

The user requirements input become part of the requirements database that is used to produce an initial plan of network use. Specifically, given the inputs from users, a look ahead algorithm places user tracks into the plan so that average contention is "minimized" (see Johnson and Werntz (1987)). Given the average profile of use, high contention periods can be identified and effort can be directed at developing solutions to reduce the contention during the high activity periods. From the generic inputs and average contention profile, a detailed plan for use can be generated from which specific allocation conflicts can be identified.

2.3 Constraints and Events

One of the major drivers in the planning of DSN use is the time in which a spacecraft can be tracked by a station. This location-time element is defined as the spacecraft *viewperiod*. In the planning of network use, the viewperiod constrains the location in the schedule where a mission pass can be placed. Figure 3 supplies a portion of the viewperiod database for the Goldstone complex for missions in the JPL-RAP. The viewperiod data shows the exact mission times that are in view of the complex for a specific week, day and year.

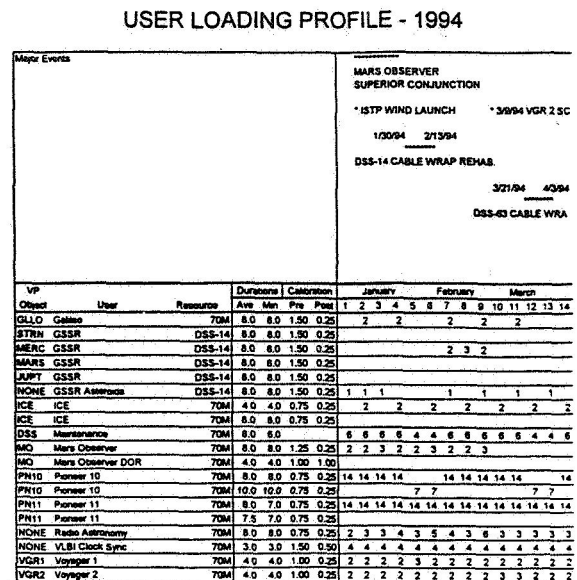
Figure 3
Mission Viewperiods at Goldstone Complex



Source: JPL-RAP database

In addition to the viewperiod constraint, major events (eg. launch, orbit insertion) are also supplied with user requests so that the planners and users can view, in the plan, the events that are associated with the requests schedule in the plan. The combination of user requirements, mission events, and viewperiod constraints are integrated to provide a 10 year plan. Figure 4 provides a snapshot for the 70 meter network for part of 1994. In Figure 4 each user of the 70 meter network is listed along with its requirements (passes per week) and major events.

Figure 4
70M Snapshot of Resource Use Plan-1994



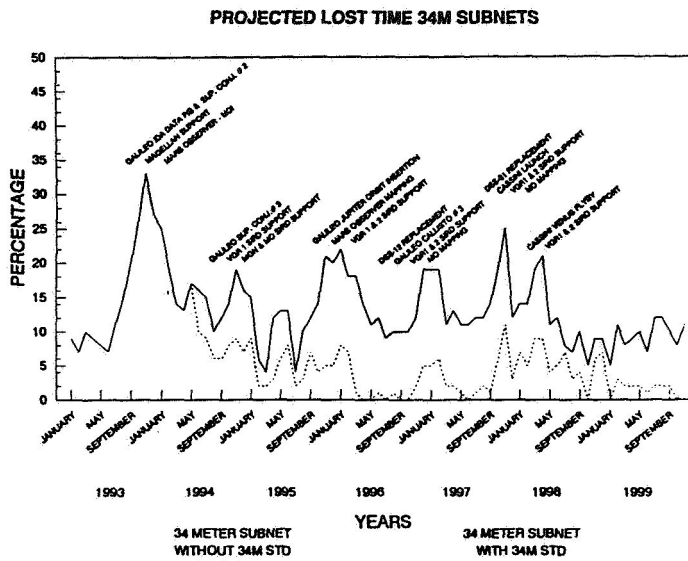
Source: JPL-RAP database

2.4 Planning Committees

Control of the resource plan and user requirements are provided by a three-tier committee process. At the top tier there is a Resource Allocation Review Board (RARB) which oversees the ten-year plan and user requirements. The Board consists of the project managers and scientists for each mission in the mission set, and meets biannually. The Board resolves the high-level contention and controls user requests and requirement changes, i.e., it provides for configuration control. For example, Figure 5 provides an overview of the percent of total 34 meter requirements (in hours) that cannot be met given the viewperiods (lost), users requests and system capabilities. The solid line shows the "lost time" from 1993 to 1999 for the entire 34 meter subnetwork if the 34S subnetwork is decommissioned when the 34B subnetwork is installed. The graph lists the major events at the spiked points. The graph also shows the benefits in terms of reduced lost time if the network is not decommissioned (see the dashed line). These types of graphs are becoming

standard output from the the JPL-RAP database. They provide a quick summary of the contention points in the schedule to be resolved. In addition, the database can allow for "what if" analysis by adding and subtracting resources from the system.

Figure 5
Analysis of Lost Time



Source: Resource Allocation Review (August 4, 1992)

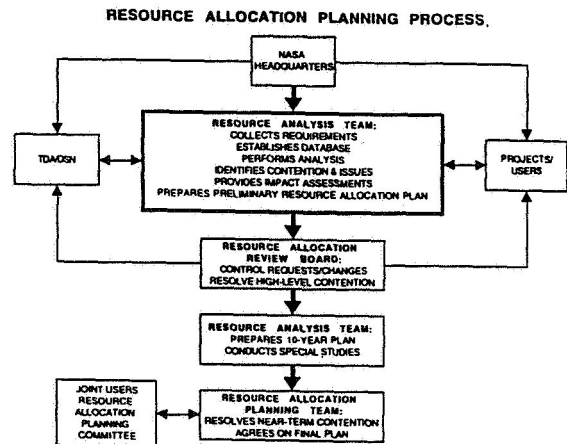
The second tier committee is the Joint Users Resource Allocation Planning (JURAP) committee which is comprised of flight project operations managers, DSN operations managers and other user operations managers. The JURAP is responsible for implementing the RARB recommendations and maintains requirements control as request become more specific and conflicts become more detailed. The third tier committee is the Resource Allocation Planning Team (RAPT) which consists of representatives from each mission user as well as DSN operations. The RAPT resolves contentions concerning specific track-by-track conflicts that are not picked-up in the other committees in their deliberations.

2.5 Process Flow Summary

Figure 6 provides an overview of the flow of the RAP process. The major elements of the process are:

- The mission set defining the current and potential users of tracking resources.
- A detailed list of network plans, characteristics and maintenance requirements which provide a resources availability profile.
- A standardized requirements input form for "generic" passes per week for each user.
- A look-ahead algorithm that places passes in the schedule so as to minimize average contention.
- A standardized set of outputs that allows planners to perform impact studies on various changes in the plans.
- A multi-tier committee process that provides for request control as the plans mature.

Figure 6
RAP Process



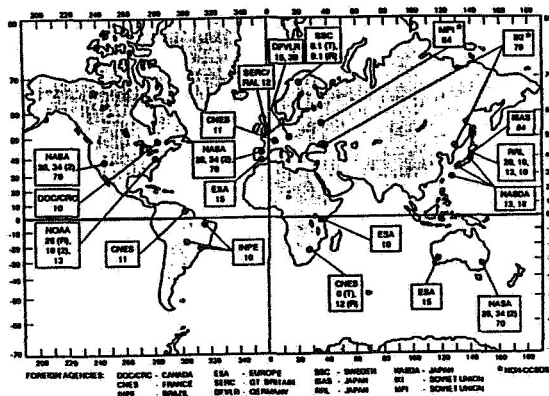
3. INTEGRATING INTERNATIONAL COMPONENTS

The purpose of this section is to show how elements of individuals plans can be integrated into a cross-support exchange system. It is axiomatic that more requirements can be met if tracking resources can be mixed from a variety of locations and agencies. Identifying potential mixes is where the use of common and standard databases can most helpful.

3.1 International Tracking Resources

The CCSDS maintains a catalog of all international tracking stations and their characteristics. This information is contained in the green book and from which Figure 7 below is taken from. This catalog provides a complete reference for each of the operating entities for each agency. For purposes of resource planning, additional information on each network's capacity and maintenance requirements, along with a profile of resource availability should become part of the JPL-TDA database that can be accessed by the JPL-RAP database. This would provide an ability to determine resource availability for different networks in each users viewperiod.

Figure 7
International Antenna Locations



Source: CCSDS Green Book

3.2 Requirements

Each network's user requirements should, to the maximum extent possible, be standardized so that plans and forecasts can be interpreted easily. Specifically, for the longer range plans from 3-10 years, generic "passes" per week for users could be the norm unless some other message form naturally emerges. Such standards could be developed through an international joint committee on network resource planning. This committee would likely consist of planning analysts whose agencies agree like to participate in standard cross-support arrangements.

With a standardized requirements input format each agency can easily examine the requirements database of other participating agencies to see if there is a resource match that can satisfy a mutually beneficial exchange of tracking time. At a minimum, a basic planning language could be developed so that ambiguity in searching for exchanges is reduced.

3.3 Common Information Sets

As mentioned previously, one of the major constraints in determining feasible plans are spacecraft viewperiods and major events. If a reliable set of user requirements profiles and associated viewperiods and events can be developed, then a set of software tools, some currently in use and which are under development (see Werntz (1992)), can be used to find feasible swaps among networks. Without a set of common and verified viewperiods for users, the ability to determine the impact of various exchanges on each agency's plans would be very labor intensive.

Algorithms for mission viewperiods by network location and link margin requirements seem to be natural first step in developing a reliable set of resource-mission matches. It is clear that such information is already available for each network alone; extending this effort to the international arena is likely not to be a daunting task.

3.4 Planning Tools

There are several software planning tools that

can assist planners in determining the benefits and impacts of possible reallocations of tracking times. Specifically, there is a PC-based program (see Werntz (1992)) that can add or delete resource availability during any schedule period and determine the average lost time impact on the plan. This utility could provide a first step in locating exchanges of time among agency plans. For example, suppose that during the fourth quarter of 1995 there is high contention on the DSN and if 100 hours of 70M equivalent support could be found for weeks 48-49 contention could be significantly reduced to a more manageable level. In exchange there could be up to 120 hours of 70M time available in weeks 2-5 1996.

3.4 Standardizing Agreements

While the development of common standardized requirements, resource availability, and network plans is necessary to facilitate the determination of feasible exchanges, implementing the exchanges into individuals plans is another matter. Like DBRS we believe that getting involved in international resource conflict resolution is a thorny problem. Instead, within each agency there should be a responsible group that identifies and coordinates potential exchanges, which has the authority to sign a work order type of arrangement to exchange tracking time (or science for tracking time). For the RAP process it should be the responsibility of the RAT to coordinate with TDA to identify potential exchanges and present them to the RARB to be ratified.

4. SUMMARY

The purpose of this paper was to expand on the theme developed by Dumas, Briggs, Reid, and Smith in which they call for the development of standardized agreements and better communication and software to facilitate international cross-support. Considerable effort and progress has been made in improving data standards and communication frequencies among ground data systems. However, not much emphasis has been placed on standardizing and integrating requirements and planning databases among agencies. Without a common set of planning standards or databases it is virtually impossible to identify and

determine the impact of potential exchanges of tracking times among agencies.

The RAP process used at JPL to plan DSN tracking time has matured to the point that it is highly automated. It could be a basic starting point for designing common planning databases. When the development of common/standardized requirements, resource availability, and network plans is resolved, it will become a considerably easier, if not a routine task, to determine feasible exchanges. As a first step we would suggest the following course be pursued:

- Each network's capacity and maintenance requirements, along with a profile of resource availability become part of a common database that can be accessed.
- An international joint committee on network resource planning should be created to develop standard requirements and schedule formats that can be accessed. These would include viewperiod determination and long-range and short-range plan formats.
- Basic software tools should be jointly developed to assist in finding unused times or feasible exchanges that could be acted upon.
- Simple exchanges of tracking time or tracking for science should be advanced through "pre-approved" standard work order arrangements.

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Appendix A Mission Set

RESOURCE ALLOCATION PLANNING				
User/Mission Planning Set 1993-2000				
Project	Launch	End of Prime Mission	End of Extended Mission	Subnet
ONGOING APPROVED PROJECTS				
DSN	—	—	—	70M/34S/34H/34B
DSS	—	—	—	70M/34S/34H/34B
GSSR	04/01/85	—	—	70M
ICE	08/12/78	08/12/88	12/15/00	70M
PN10	03/02/72	01/15/74	12/30/99	70M
PN11	04/05/73	01/15/75	08/01/95	70M
PN12	05/20/78	01/18/79	10/08/92	70M/34S
RASA	—	—	—	70M
VGR1	08/05/77	12/31/80	12/15/15	70M/34S/34H/34B
VGR2	08/20/77	10/15/88	12/15/15	70M/34S/34H/34B
CAS	10/13/87	TBD	TBD	70M/34H/34B
GLL	10/18/88	10/07/87	12/31/99	70M/34S/34H/34B
ISTP-Geotail	07/14/92	07/14/95	TBD	34S/28M
ISTP-Wind	01/15/94	08/15/98	TBD	34S/28M
MGN	05/04/89	05/04/91	06/21/93	70M/34S/34H
MO	08/25/92	02/03/96	12/22/97	70M/34H/34B
ULS	10/05/90	08/11/95	12/30/00	70M/34S/34H/34B
HRMS	01/01/98	12/30/00	—	70M/34B
MARS-94	03/15/95	08/01/95	TBD	70M/34H
CANDIDATE PROJECTS FOR ADVANCED PLANNING				
ISO	11/94	11/98	N/A	34S/DSS-12/28M
DSPSE	1/21/94	9/94	N/A	70M/34S/28M
PSI/Foreshot	11/23/94	12/10/97	12/30/98	70M/34H
NEAR	01/15/98	8/30/00	8/30/05	70M/34H
PIUS Flyby	02/01/98	TBD	TBD	34H
MESUR	12/08/98	2/01/06	2/01/08	70M/34H/34B
SOCCEP	06/01/00	TBD	TBD	34B

HRMS - High Resolution Microwave Survey
 ISO - Infrared Space Observatory
 MESUR - Mars Environmental Survey
 NEAR - Near Earth Asteroid Rendezvous
 DSPSE - Deep Space Program Science Experiment
 SOCCEP - Sample of Comet Comet Earth Return